200 Ω Chopper R&D Progress

G. Saewert

Project X collaboration meeting

April 10, 2012

Outline

- Development approach and objectives
- Subsystem development progress
  - Vendor contributions
  - Status of driver development
- Summary

200 Ω approach pros and cons

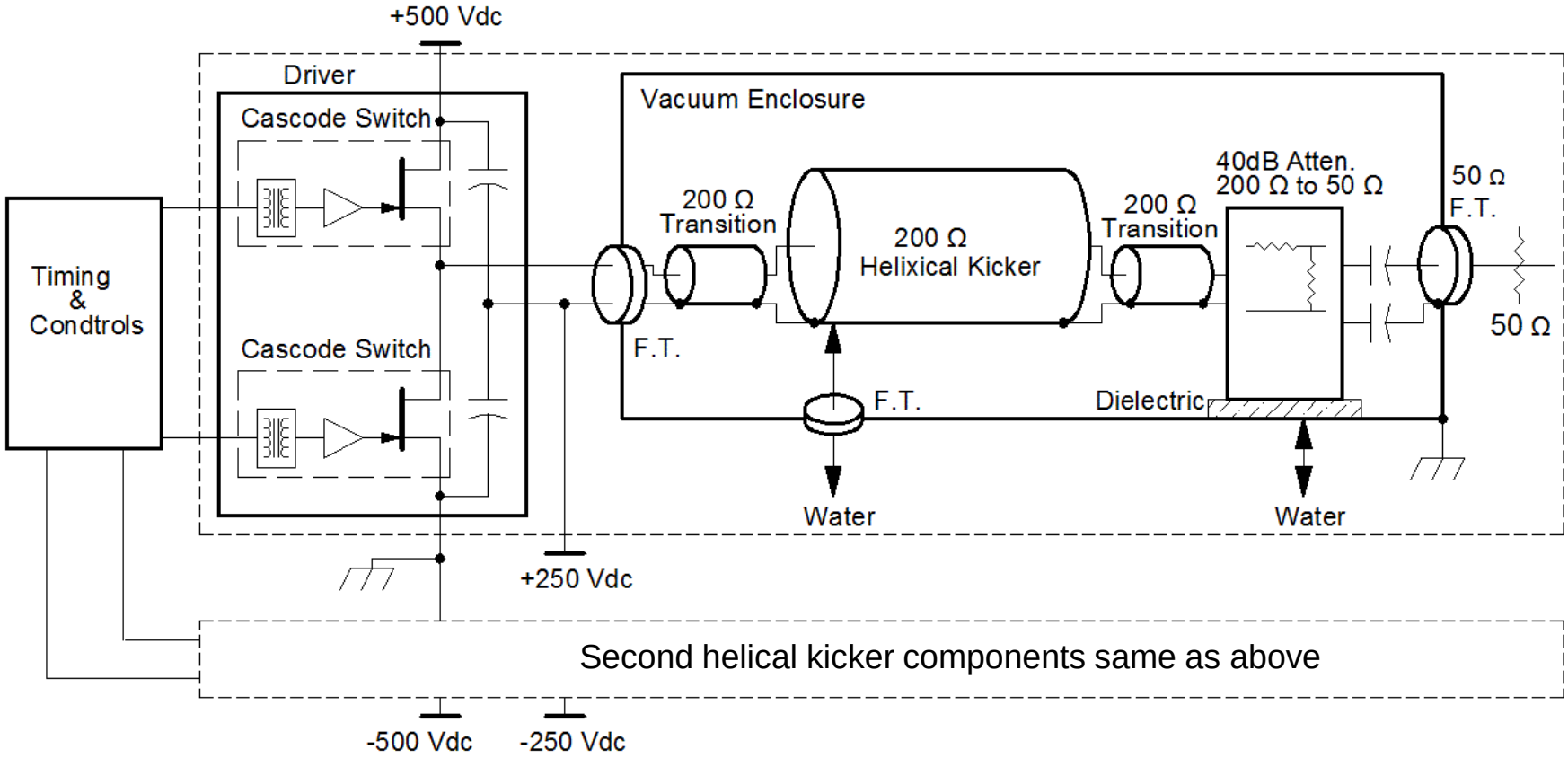
- Pros
  - Lower power dissipation in the driver, kicker structure and load
  - We have chosen for the driver to be DC coupled to avoid base line shifting of AC coupling
- Cons
  - Neither a driver, nor 200 Ω transmission lines, feed-throughs, or load are commercially available

Design requirements

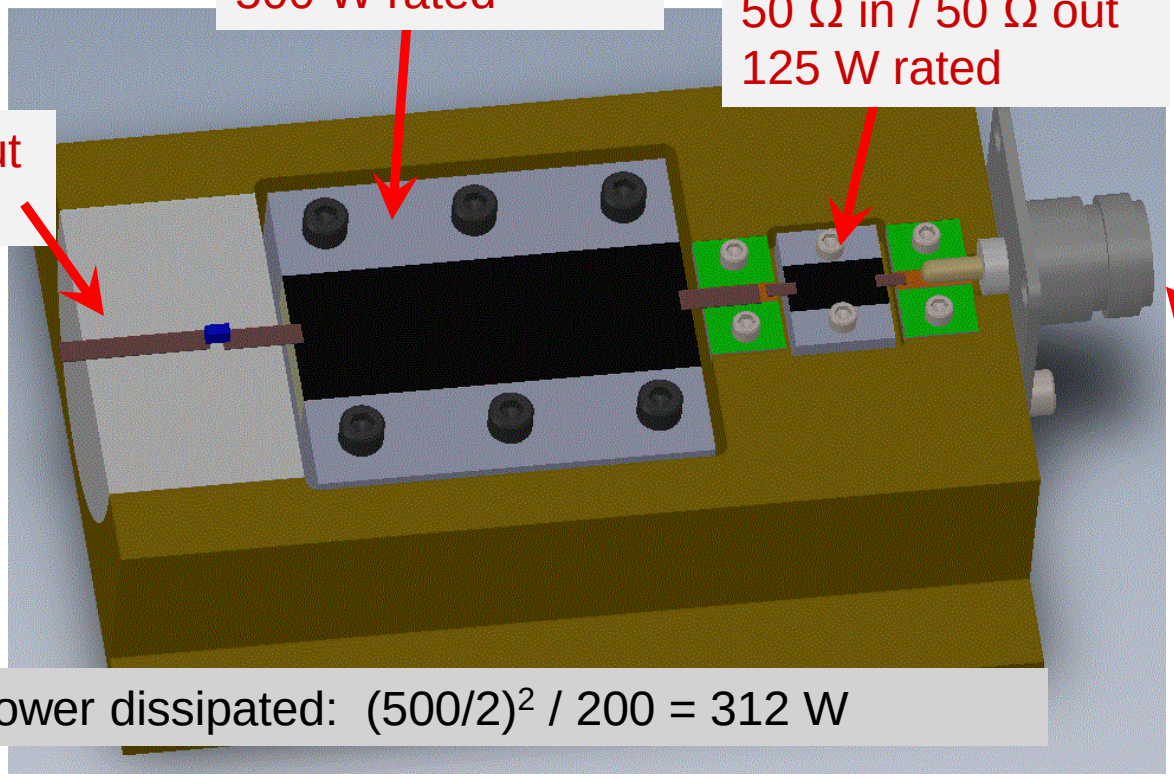
- Present design effort targets these objectives
  - Potential to reach 500 V
  - Switch either of two chopping schemes
    - Two 500 volt kickers to kick beam out
    - Or, two +/- 250 volt kicker to kick beam both in and out
  - DC coupled drive to the kicker
  - ~2 ns rise time
  - Be able to kick out one bunch (~1.5 ns wide flat top)
  - Handle power dissipation for high duty factor
  - Support variable high duty factor waveforms
  - Handle rep rates, ~30 MHz

System block diagram as currently proposed

Two helical kickers: their interconnections and biasing



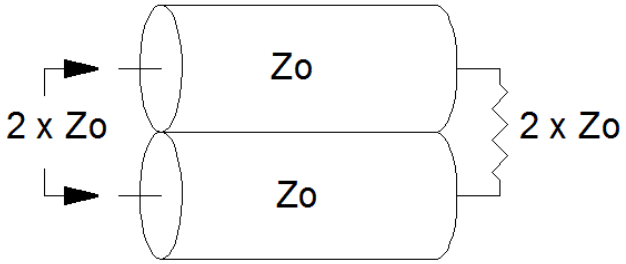
200 Ω termination prototype designed by Elab, Inc.

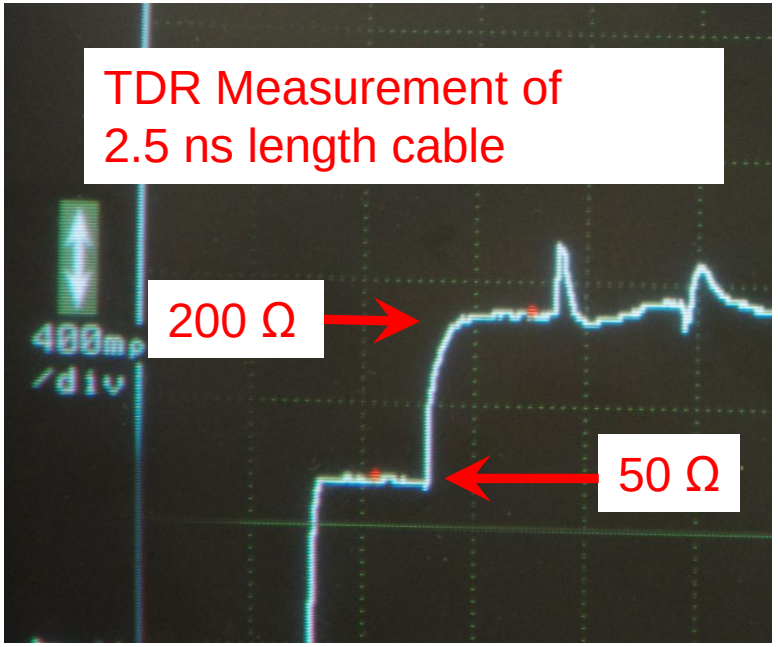


Total power dissipated: $(500/2)^2 / 200 = 312$ W

200 Ω transmission lines

- Transmission line options
  - Home made coax
  - Home made microstrip line
  - Dual 100 Ω coax
- Dual 100 Ω coax under evaluation

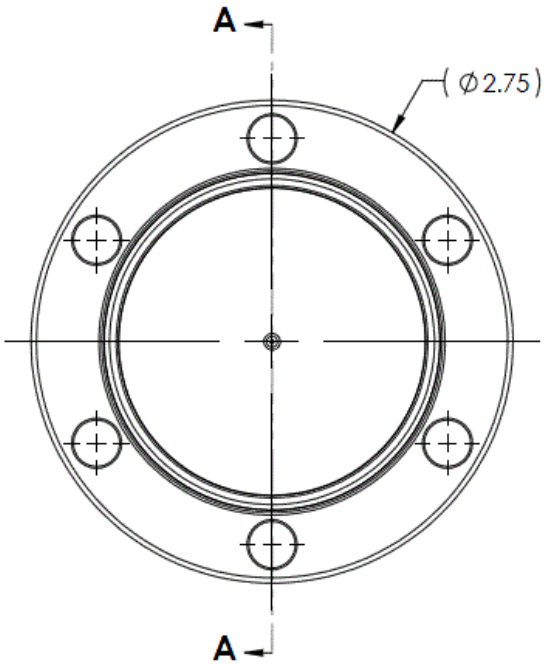


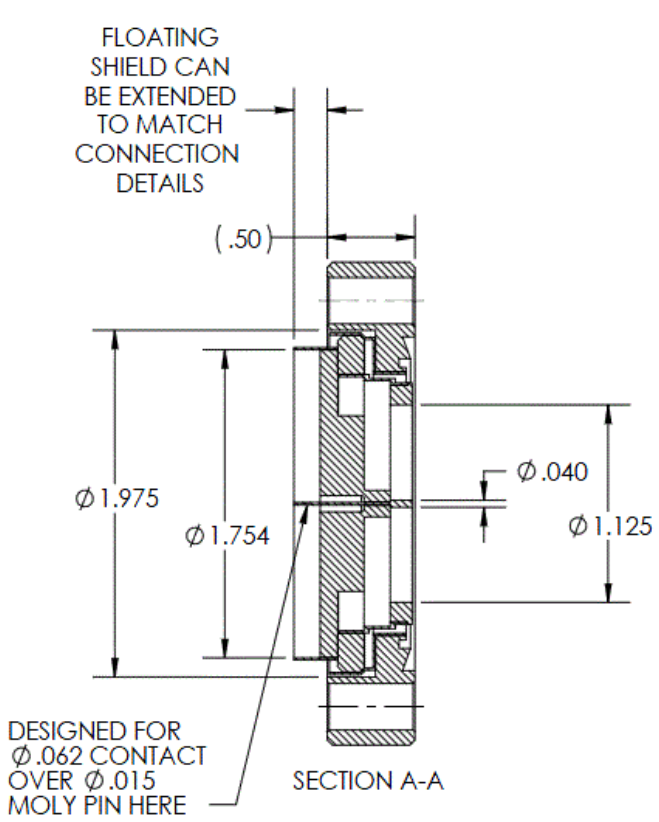


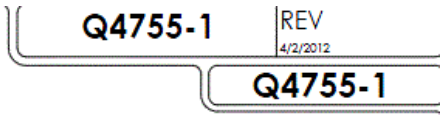
  - Measurement shows 0 – 1.75 ns rises from 125 Ω to ~200 Ω
  - Use may require additional compensation
  - 100 Ω coax supplied by Haverhill Cable

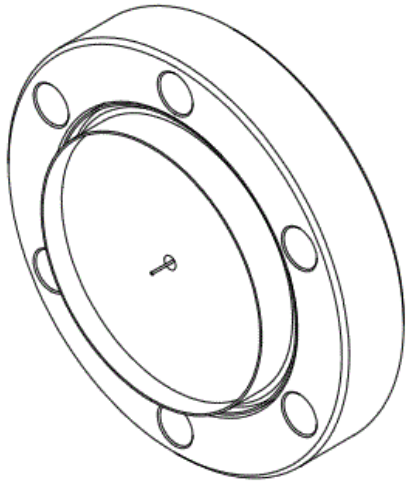
Custom feedthru by MPF Products, Inc.

Low capacitance isolated feedthru



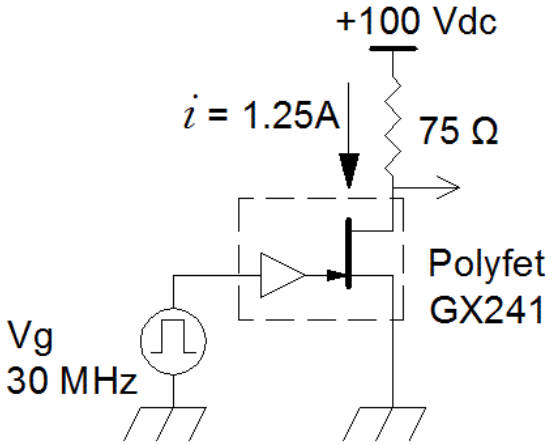






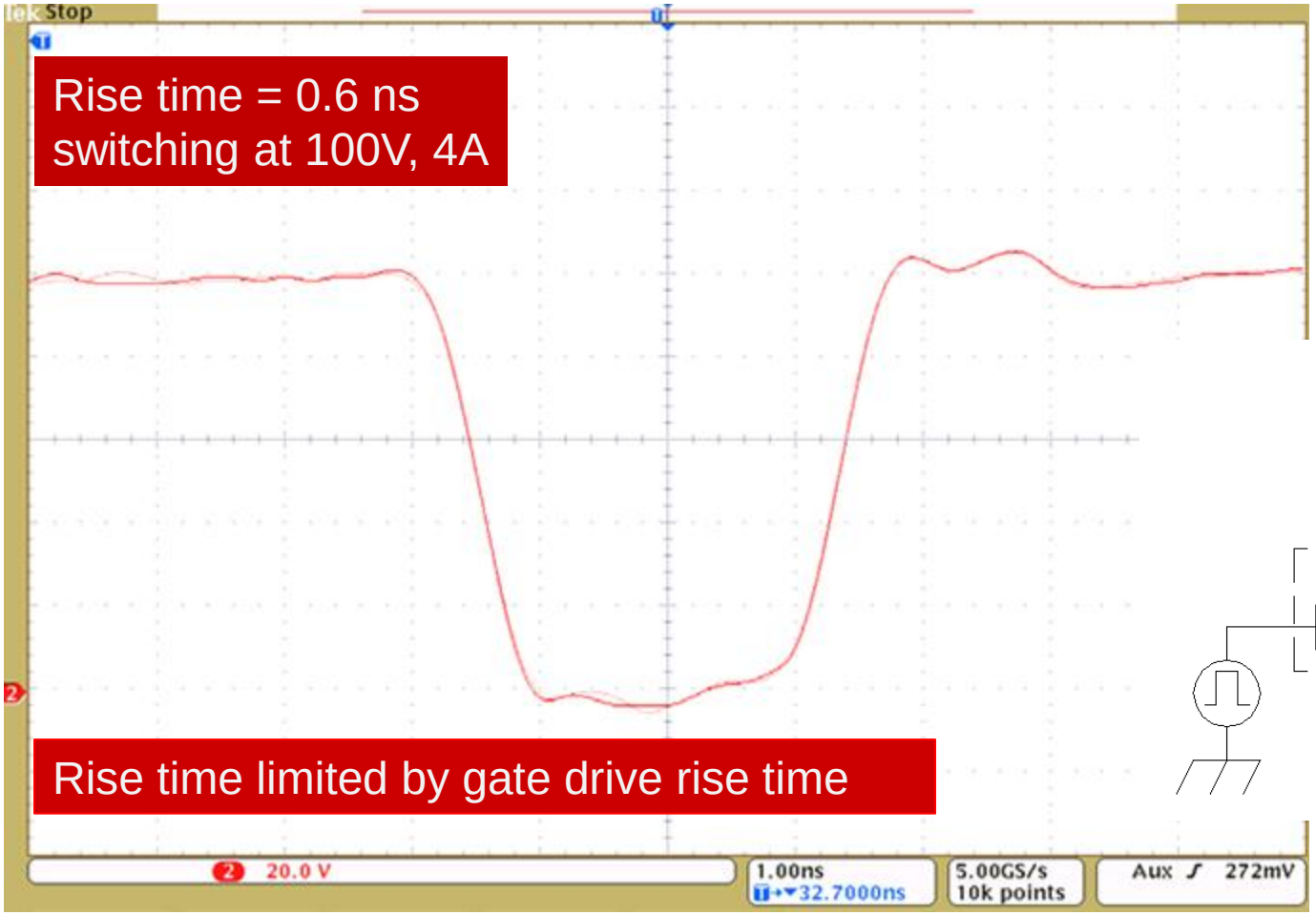
Driver: GaN FET switching power

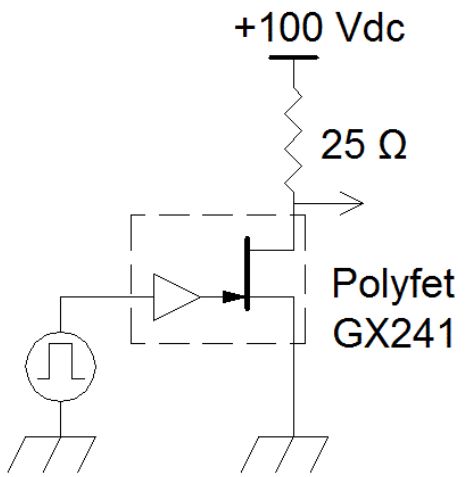
- GaN FET power dissipation test
  - Switched at 30 MHz CW
  - Duty factor = 50 % (62 W delivered)
    - Case temp = 86 °C
  - Duty factor = 25% (31 W delivered)
    - Case temp = 81 °C
- Test performed without a heat sink
  - FET soldered to G-10 PCB
  - No forced air flow over the transistor
- Conclusions
  - Switching losses dominate over conduction losses at 30 MHz
  - Obtaining adequate cooling should be possible



Gx241 specs:
Coss = 8.5 pF
Bvdss = >200V

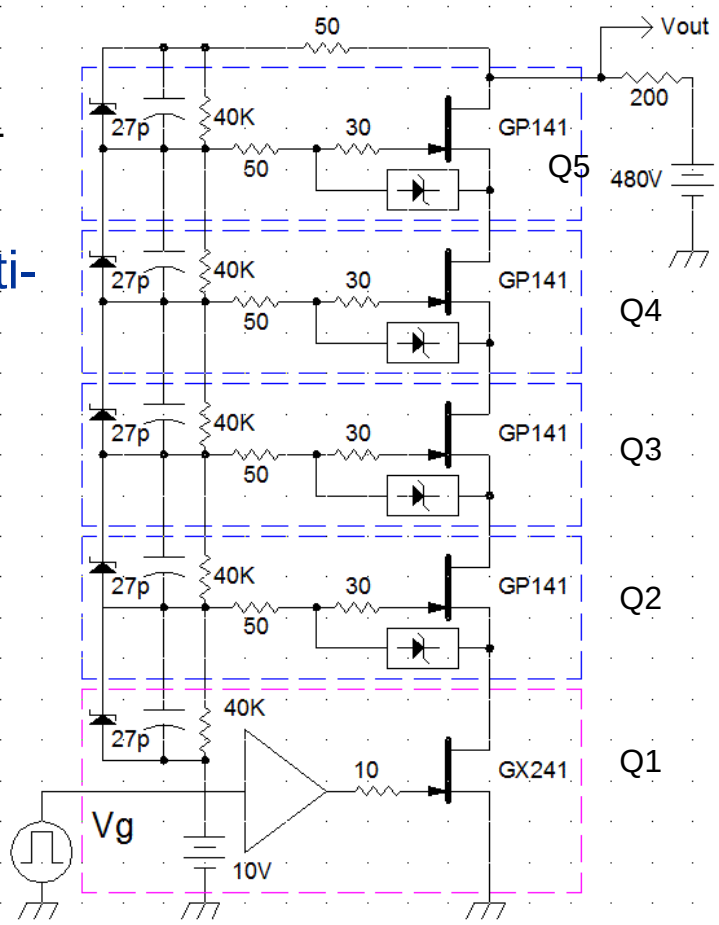
GaN FET switching speed



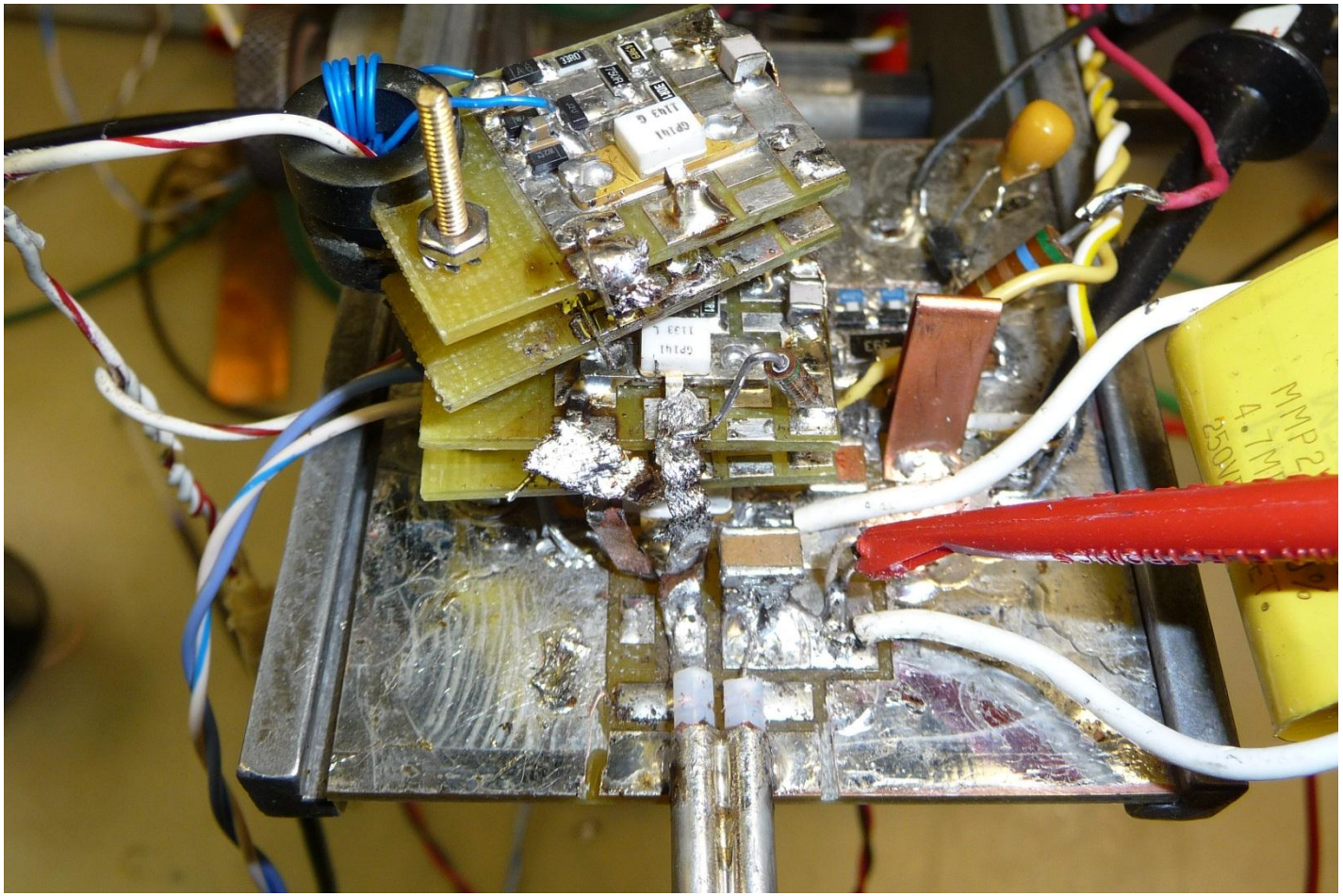


Cascode switch design

- Motivation for multi-FET circuit
  - Currently available devices limited to 200 V
  - However, switching losses at 100 V per FET are more manageable
- The appeal of cascode scheme for multi-FET switch
  - FETs turn on together and share voltage
  - There is only one control signal
  - Has the potential of switching fast
- Major components
  - 1 common source driver stage (Q1)
  - 4 common gate stages in cascode (Q2-Q5)
  - RC divider string forces voltage sharing
  - Voltage clamps protect Q2-Q5 gates



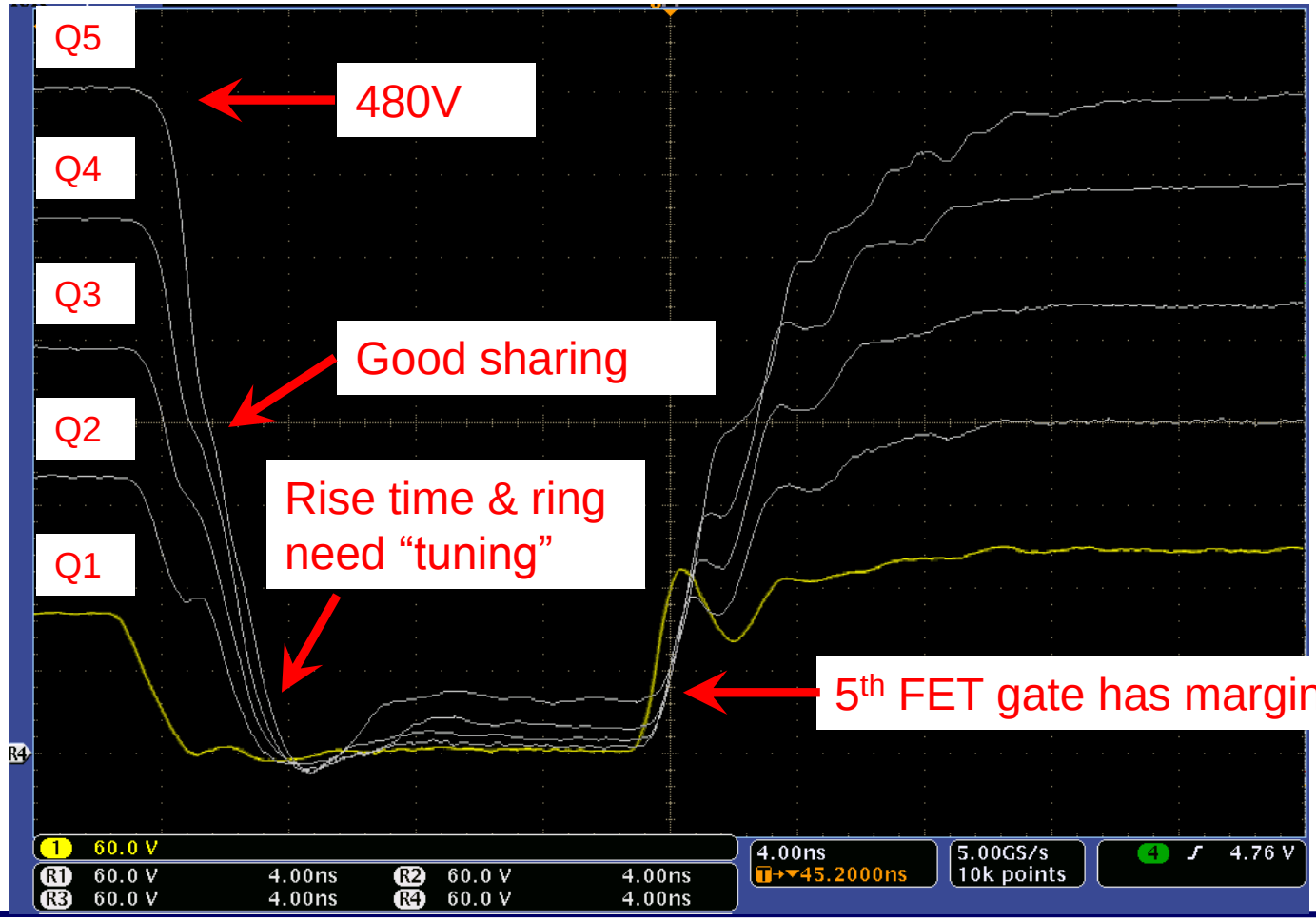
5 FET Cascode switch



Cascode switch design issues

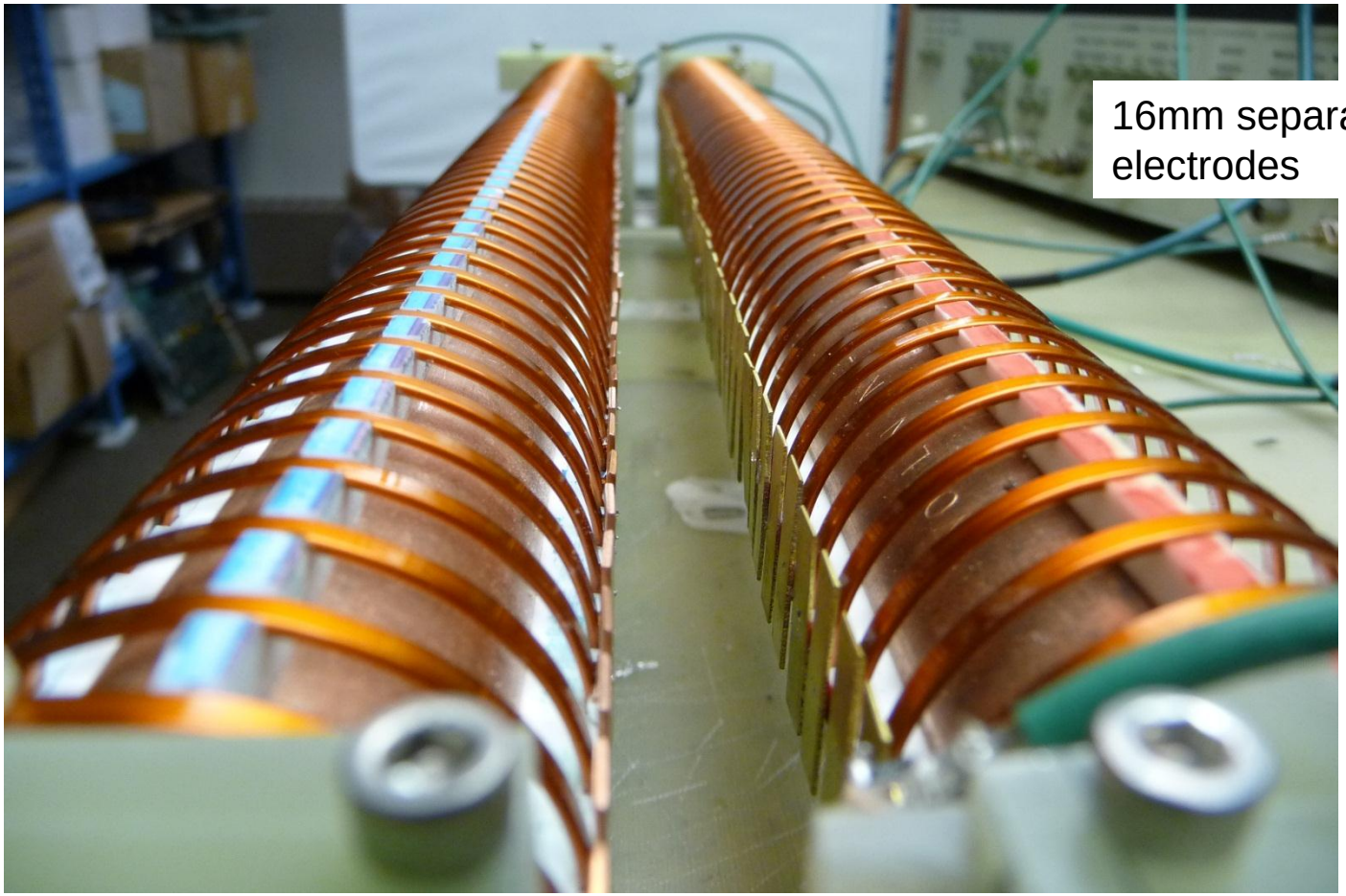
- Major issues
  - Design common source driver stage having <1 ns rise/fall time
  - Provide adequate gate drive voltage in the common gate stages
    - During edges while turn on
    - Gate drive level decreases on upper FETs
  - Minimize output overshoot and ring
- Minimize and counteract parasitic capacitance and inductance
  - Increase FET switching losses
  - Responsible for output overshoot and ring
  - Impair output rise time

Switching to 480 V



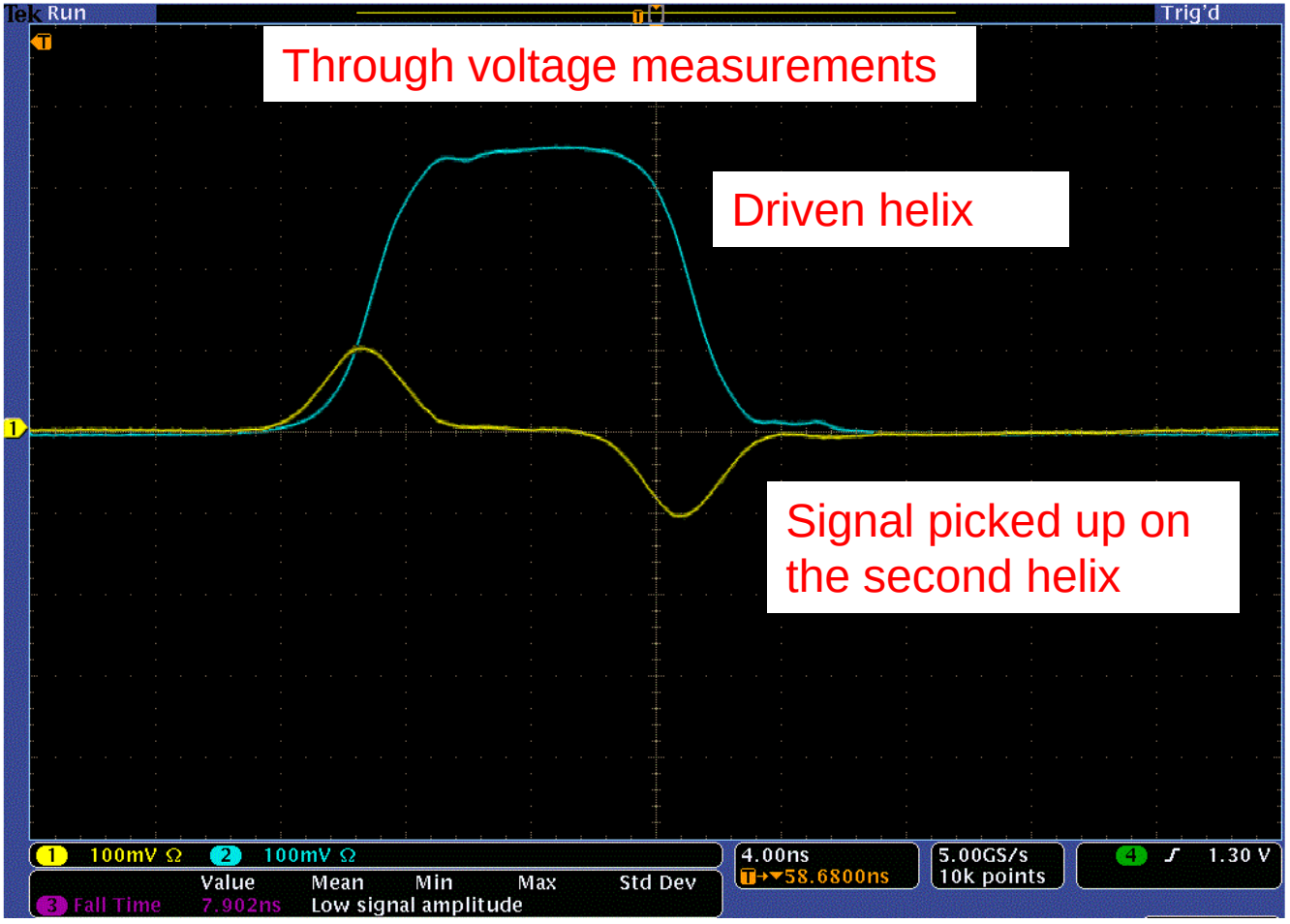
Ferrite beads in drain circuits dampen overshoot and ring

Two helixes 16mm appart



16mm separation between electrodes

Coupling effect

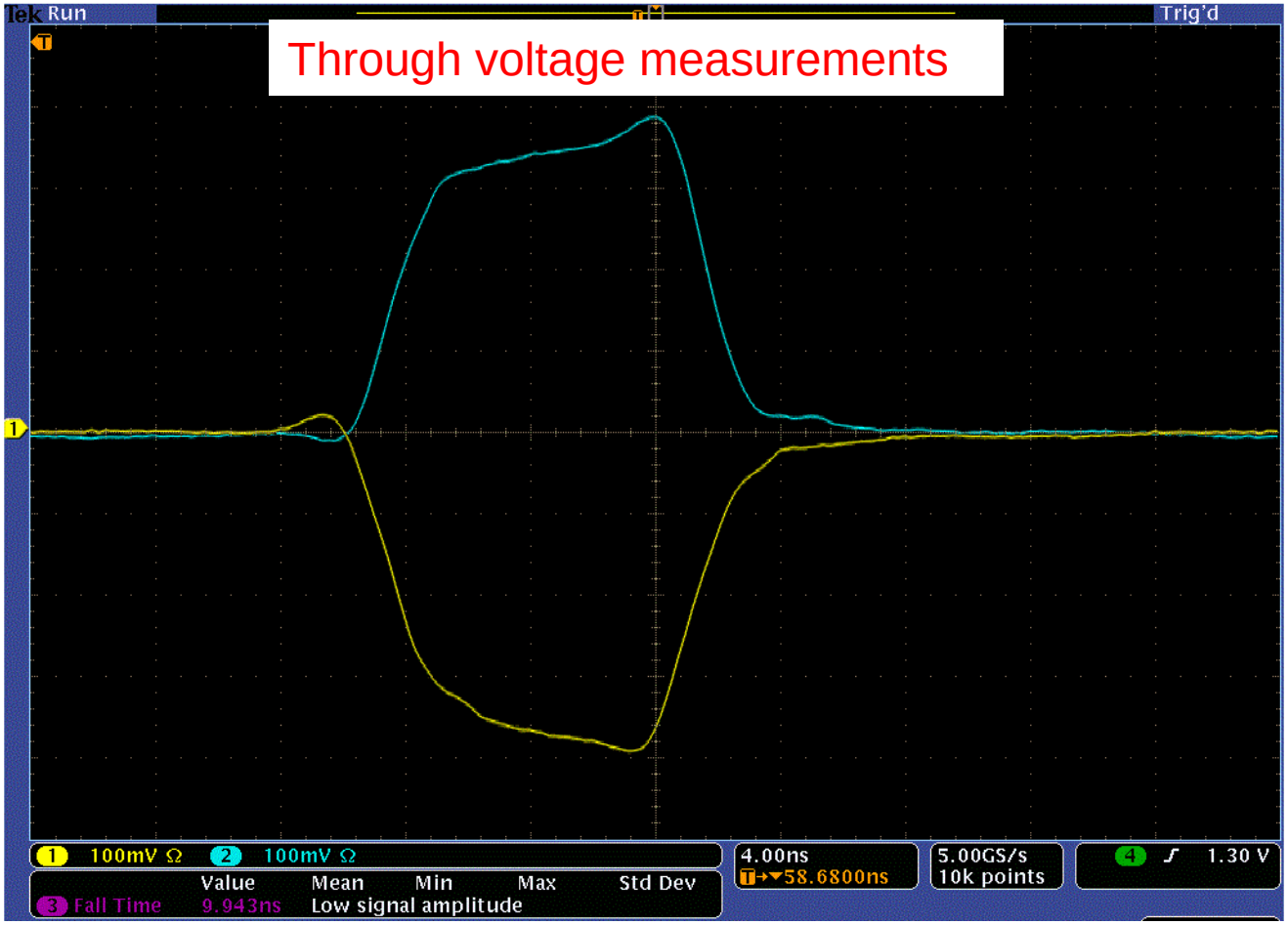


Driver = 2 ns rise/fall

Both helixes are resistively matched to 50 Ω

Both helixes wound in the same direction

Helixes driven out of phase



Driver = 2 ns rise/fall

Both helixes are resistively matched to 50 Ω

Both helixes wound in the same direction

Summary

- All subsystems have are under development to some degree
  - Mechanical Support Dept. is working on kicker design
  - 200 Ω transmission lines are under evaluation
  - One feed thru vendor has submitted one proposal
  - We are to receive 200 Ω termination prototype in April
- Driver design is approaching 500 V